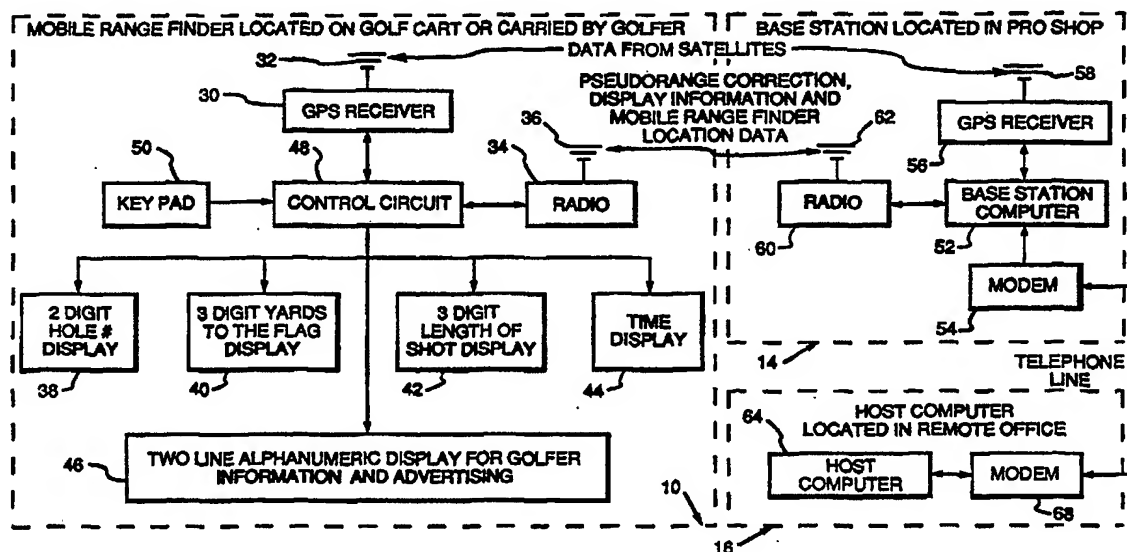




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(54) Title: METHOD AND APPARATUS FOR DETERMINING LOCATION AND INDICATING SELECTED DISTANCES BETWEEN POINTS ON A GOLF COURSE



(57) Abstract

A method and apparatus for determining location and indicating selected distances between points on a golf course including a base station (14) having a GPS receiver (56), computer (52), and a radio frequency transmitter or transceiver (60), and a plurality of mobile range finder units (10) each having a GPS receiver (30), a radio frequency transmitter or transceiver (34), annunciators (38, 40, 42, 44), and a key pad (50). The base station (14) uses the GPS satellite information to continuously determine injected positional and system error and to transmit offset signals to the mobile units. The mobile units use the transmitted offset signals and independently received GPS location information to calculate actual position and altitude of the mobile unit and use positional information to calculate actual distance to and between selected points on the golf course.

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1 Specification

2

3 METHOD AND APPARATUS FOR DETERMINING LOCATION
4 AND INDICATING SELECTED DISTANCES
5 BETWEEN POINTS ON A GOLF COURSE
6

7

8 BACKGROUND OF THE INVENTION9 Field of the Invention

10 The present invention relates generally to position
11 and distance determining apparatus and methods, and more
12 particularly to a system and method for accurately
13 determining the position of a golfer on a golf course and
14 for calculating the distance from the golfer to various
15 selected points on the course. The system also provides
16 other information and provides for electronic golf course
17 play management.

18

19 Description of the Prior Art

20 Numerous attempts have heretofore been made to
21 improve management and profitability of golf course
22 businesses by providing various means for assisting the
23 players in determining various distances on the course so
24 as to accelerate play of the game, and by providing means
25 for tracking the position of golfers on the course for
26 allowing the course executive to monitor the speed of
27 play. Whereas fairway distances have classically been
28 determined by referring to marked fairway or pathway
29 points, more recent attempts at providing distance
30 indication have included the use of various optical
31 sighting devices, electromagnetic position detection
32 systems and electronic ranging systems. For example, one
33 such system described in US Patent No 4,703,444 utilizes
34 three fixed transmitters located on the golf course to
35 provide Rf ranging signals to portable interrogation units
36 and a portable surveying unit to locate fixed features
such as holes and hazards.

1 Another approach is disclosed in US Patent No
2 3,868,692 which describes a system utilizing RF
3 transmitters located on each of the eighteen greens and an
4 eighteen channel receiver that is carried by the golfer.
5 The receiver measures the relative field strength of the
6 Rf field generated by the transmitter on the green of
7 interest to determine the range to the green.

8 In US Patent No 4,136,394 a system is described that
9 utilizes a transducer located on each green which responds
10 to a radio pulse generated by a remote unit carried by the
11 golfer and generates a sonic or ultrasonic pulse that is
12 received by the remote unit. The time required for the
13 sound to travel from the green to the golfer is measured
14 by the unit and the distance to the hole is calculated
15 based upon the speed of sound and the elapsed time.

16 A radio transmission system using radio wave
17 triangulation is disclosed in US Patent No 4,926,161 and
18 a buried conductor electromagnetic detector system for
19 determining distance to green information is disclosed in
20 US Patent No 5,044,634.

21 Although not related to golf course applications, a
22 somewhat relevant electronic vehicle locating system is
23 disclosed in US Patent No 5,119,102. The system uses
24 radio signals generated by the NAVSTAR Global Positioning
25 System (GPS) satellites and vehicle carried receiving
26 units capable of determining their position using
27 information received from the satellites.

28 The NAVSTAR Global Positioning System is described in
29 detail in numerous publications including "GPS NAVSTAR
30 Users Overview" prepared and published by ARINC RESEARCH
31 for the Program Director, NAVSTAR Global Positioning
32 System Joint Project Office. Basically, the Global
33 Positioning System includes a multitude of satellites in
34 orbit around the earth at an altitude of approximately
35 10,500 miles. These satellites, which are commonly called
36 NAVigation Systems using Timing And Ranging (NAVSTAR)
37 satellites, are actively time synchronized by atomic

1 clocks and send information to earth via radio signals,
2 such information including the location of the satellite,
3 time information and range codes. The United States
4 Department of Defense (DOD) monitors and maintains these
5 satellites and provides access thereto free of charge to
6 all users. The commercially usable signals received from
7 the satellites are known as C/A code (course/acquisition)
8 signals. The DOD causes pseudo-random noise to be
9 injected into the C/A code to limit the accuracy of the
10 C/A code signals. The intentionally injected noise
11 signals, when combined with additional system errors such
12 as satellite clock bias, atmospheric distortion and
13 gravitational effects, limit the position determining
14 accuracy of a ground based GPS receiver to approximately
15 100 yards of actual position. The use of a simple GPS
16 receiver is thus not suited to use by a golfer to
17 determine his position on a golf course fairway.

18 Furthermore, in addition to the problem of dealing
19 with the injected noise signal and additional system
20 errors, the simple use by a golfer of a GPS receiver to
21 determine his position is not practical because such
22 receiver provides position information in terms of
23 longitudinal and latitudinal coordinates which must be
24 interpreted in relation to a map of the region of
25 interest, and such use would materially detract from play
26 of the game.

27

28 SUMMARY OF THE PRESENT INVENTION

29 It is therefore a principal objective of the present
30 invention to provide a system which makes transparent use
31 of GPS technology and modern computer technology to
32 provide accurate positional and distance information to
33 golfers.

34 Another objective of the present invention is to
35 provide a system of the type described which allows a
36 golfer to determine the distance from his present position
37 to a hole, hazard or other point on a golf course.

1 Still another objective of the present invention is
2 to provide a system of the type described which allows a
3 system operator and/or golf course manager to communicate
4 information to a golfer on a real time basis.

5 A further objective of the present invention is to
6 provide a system of the type described which can be used
7 to substantially improve the management of a golf course
8 by providing important information to a course operator or
9 system manager.

10 Briefly, a preferred embodiment to the present
11 includes a fixed base station having a GPS receiver, a
12 base station computer and a radio frequency transmitter or
13 transceiver, and a plurality of mobile range finder units
14 each of which include a GPS receiver, a radio frequency
15 receiver or transceiver, computational electronics
16 annunciators and a key pad for user entry of information
17 and/or selection of function. The function of the base
18 station is to use GPS satellite information to
19 continuously determine injected positional and system
20 error and to transmit offset signals and other information
21 to the mobile units. The mobile units in turn use the
22 transmitted offset signals and independently received GPS
23 location information to calculate actual position and
24 altitude of the mobile unit and use such positional
25 information as a means to compute actual distance to and
26 between selected points on the golf course. The system
27 may also include the capability of transmission from
28 mobile unit to base station, and the base station may be
29 coupled to a remotely located host computer which controls
30 and/or monitors its operation.

31 An important advantage of the present invention is
32 that it provides an easy to use electronic aide to golfers
33 which enhances their play by providing them with accurate
34 position and distance information.

35 Another advantage to the present invention is that it
36 requires no additional use of optical or mechanical
37 apparatus.

1 Another advantage to the present invention is that it
2 serves to accelerate the speed of play of the game thereby
3 enhancing the profitability of the golf course.

4 Still another advantage of the present invention is
5 that it allows at least one-way communication between the
6 club house and the players.

7 Yet another important advantage of the present
8 invention is that it provides information which can be
9 used to improve golf course management and facilities
10 usage.

11 These and other advantages of the present invention
12 will no doubt become apparent to those skilled in the art
13 after having read the following detailed description of a
14 preferred embodiment depicted in the several figures of
15 the drawings.

16

17 **DETAILED DESCRIPTION OF THE DRAWING**

18 **Fig. 1** is a pictorial view generally illustrating the
19 environment and operational interrelationship of system
20 components in accordance with the present invention.

21 **Fig. 2** is a block diagram illustrating the principal
22 operative components of a system in accordance with the
23 present invention.

24 **Fig. 3** is a pictorial view illustrating one possible
25 design of a mobile range finder and annunciator unit in
26 accordance with the present invention.

27 **Fig. 4** is a block diagram generally illustrating the
28 principal functional components of the control circuit of
29 **Fig. 2**.

30 **Fig. 5** is a flow chart illustrating operation of a
31 GPS receiver.

32 **Fig. 6** is a flow chart illustrating calculation and
33 use of differential correction signals in accordance with
34 the present invention.

35 **Figs. 7a and 7b** are flow charts illustrating overall
36 operation of the system of the present invention.

1 DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

2 Referring now to Fig. 1 of the drawing, a pictorial
3 view is presented showing a plurality of GPS satellites
4 within view of a golf course having an installed golfer
5 location and distance measuring system in accordance with
6 the present invention. As depicted, the preferred
7 embodiment is comprised of two main subsystems including
8 a mobile range finder (MRF) unit 10 which is carried by a
9 golfer, or mounted on a golf cart 12, and a base station
10 14 which is typically located in the pro shop. The system
11 may also include a host computer system 16 housed in a
12 location remote from the golf course. GPS receivers for
13 receiving data broadcast from the NAVSTAR satellites a-e
14 are disposed in each mobile unit 12 and the base station
15 14. In its simplest form the system requires only one
16 centrally located general purpose communications
17 transmitter, as evidenced by the antenna 18, to
18 periodically broadcast differential correction signals and
19 other information to a radio receiver in each mobile unit
20 10.

21 Whereas prior range measurement systems for golf
22 courses have required the placement of numerous fixed
23 sensors transmitters, transponders or markers on the golf
24 course the present system requires no fixed facility other
25 than the base station. The basic range measurement
26 technique employed in the present invention is based upon
27 a receiver only design for the mobile units. However, an
28 alternative embodiment may also include a transmitter for
29 communicating information back to the base station. As
30 will be explained below, the system allows one or more
31 golfers to obtain measurements of their range to the flag
32 20, to a sand trap 22, to a hazard 24, or the distance of
33 a completed shot. Each mobile unit has the capability of
34 quickly determining and displaying or audibly
35 communicating correct range/distance information without
36 interference from other mobile units on the course.

1 In an alternative embodiment the system also includes
2 a transmitter in each mobile unit 10 to repetitively
3 transmit information relating to its location back to the
4 base station. Software allows the course operator to
5 utilize such data to manage the golf course with improved
6 efficiency and less cost than is now experienced. For
7 instance if desired by the operator, the system will
8 automatically track the speed of play of the group
9 associated with each mobile unit on the course, and if any
10 foursome should fall too far behind the group ahead of
11 them, a message can be sent to the slow playing foursome
12 to request that they speed up play. Alternatively, a
13 course ranger could be notified of the delay on a
14 specially addressed mobile unit. The mobile transmitters
15 and receivers, and the base station transmitter and
16 receiver can also be used as a means of providing
17 intercommunication between players and clubhouse.

18 As indicated above, the use of a GPS receiver to
19 determine position is well known. However, the difficulty
20 of use and the inherent inaccuracies associated with use
21 of such a receiver alone make it impractical for golf
22 applications. The DOD injected noise signals combined
23 with additional system errors such as satellite clock
24 bias, atmospheric distortion and gravitational effects
25 limit the position determining accuracy of a ground based
26 GPS receiver to a distance clearly outside the range of
27 usefulness to a golfer. Thus, in addition to the GPS
28 receiver, the present invention includes means to
29 determine such errors and then, through additional signal
30 processing, eliminate the error and determine the "true"
31 position of the mobile unit.

32 The system utilizes a technique called "real time
33 differential positioning" to continuously and accurately
34 determine the actual location of each mobile receiver and
35 thus, the position of the corresponding golfer on the
36 course. In accordance with the present invention the
37 coded satellite range signals transmitted by each orbiting

1 satellite are simultaneously received by the GPS engines
2 in both the base station 14 and each mobile unit 10, and
3 are processed by microprocessors which compute location
4 and distance (and altitude) solutions. However, the
5 computations made at the base station differ from the
6 ultimate computations made in the mobile units.

7 To remove the pseudo random errors injected by the
8 DOD as well as additional system error, such as satellite
9 clock bias, atmospheric distortion and gravitational
10 effect and thus achieve the required accuracy of less than
11 three yards, the GPS base station receiver installed at a
12 known permanent golf course location, such as the pro
13 shop, determines its apparent position and computes an
14 offset to its actual position.

15 More specifically, upon installation, the precise
16 location (latitude, longitude and altitude) of the base
17 station is determined via GPS survey techniques and is
18 recorded into the computer's system memory. The base
19 station receiver thus continuously determines its apparent
20 location in the same manner as does each mobile unit.
21 However, because the base station receiver was programmed
22 during its installation to know precisely where it is
23 actually located and since it does not move, it can use
24 its known location and the calculated "apparent location"
25 to continuously determine the amount of error or "offset".
26 The offset information can then be periodically sent via
27 radio transmission to each mobile unit operating on the
28 course, and each mobile unit can in turn apply such
29 information as a correction factor to its own calculated
30 location. The result of this calculated solution provides
31 an accurate indication of the location of each mobile unit
32 at any point that such information is desired.

33 To then determine the distance from the mobile unit
34 to a hole (or hazard) requires that the mobile unit also
35 know where the hole (or hazard) is located. Since the
36 hole location is normally moved on the green daily, the
37 course operator must establish a fixed number of locations

1 or sectors (generally 3-7 per green) where the hole will
2 be placed, and develop a schedule for the preassigned hole
3 placement. A hole location schedule is then loaded into
4 the base station computer and, as each mobile unit is
5 turned on, the base station computer transmits a message
6 to the unit telling it the location of each hole on each
7 green for that particular day, and the locations of
8 particular points on the hazards, e.g. a near side point
9 and a far side point. This location information is then
10 stored in the mobile unit's memory and is subsequently
11 used to calculate the precise distance from the cart to
12 the hole or hazard. However, the software in the base
13 station computer allows the golf course operator to
14 override the pre-programmed daily pin placement and hazard
15 location schedule for any or all fairways if so desired.

16 The calculation of distance using GPS receivers is
17 incorporated in many types of navigation equipment which
18 in most cases require that the manufacturer or the
19 operator of the equipment enter the coordinates of a fixed
20 point of interest. However, unlike such prior art
21 systems, the present invention automatically transmits the
22 location and altitude of the fixed points, holes and
23 hazards, etc. to the mobile unit, thus eliminating the
24 need for operator input. This information is transmitted
25 on the same radio channel that is used for the
26 differential correction signal.

27 Since the mobile unit is located on a golf cart, or
28 is carried by a golfer, it can, by comparing its
29 calculated and corrected position coordinates to the
30 internally stored coordinates of a pin or hazard, provide
31 a direct distance and altitude measurement to a particular
32 hole or hazard without the need for the additional
33 subtraction of any estimated offset distances from
34 markers such as water sprinkler heads or other permanently
35 imbedded markers in the fairway.

36 The mobile range finder unit also includes the
37 capability of measuring and displaying the distance the

1 ball has traveled for any golf shot made by the golfers
2 using the system. This feature can be activated for any
3 or all shots as desired by the individual player.

4 In that the system also incorporates a means of
5 counting the number of rounds of play for which each
6 mobile unit is actually used, this feature gives the
7 system owner the ability to charge the golf course
8 operator a fee based upon the usage of the units. In a
9 typical case, the golf course operator will regularly pre-
10 purchase the right to use the mobile units for a specific
11 number of rounds of golf depending upon their expected
12 usage. These pre-purchased rounds will then be programmed
13 into the memory of the golf course base station computer
14 by means of an electronic download via a telephone modem
15 hookup arrangement from an automatic, host computer system
16 at some remote location. The host computer will
17 simultaneously transfer the credits for the purchased
18 number of rounds to the particular base station and
19 automatically generate the appropriate invoice and other
20 accounting information on the base station printer at the
21 golf course. Purchased rounds will first be stored in the
22 base station computer of the golf course and then be
23 individually transferred to the respective mobile units as
24 required via a signal over the base station radio
25 transmitter. One credit will be extended each time a
26 mobile unit is turned on from the base station. Once
27 turned on, the mobile unit will work for only the time
28 period normally required to complete a round of golf, with
29 enough spare time allowed to insure that every round can
30 actually be completed.

31 Referring now to **Fig. 2** of the drawings, the
32 principal functional components of the mobile range finder
33 and annunciator unit 10, the base station 14, and the
34 remote office 16 are depicted in a block diagram. A
35 subsystem in the mobile unit 10 includes an electronic
36 module that consists of a global positioning receiver 30,
37 a GPS antenna 32, a radio modem 34 having a radio antenna

1 36, numeric displays 38, 40, 42 and 44, and an alpha
2 numeric display 46, control circuitry 48, and front panel
3 keypad switches 50 all housed in a weather proof enclosure
4 which may resemble that illustrated in **Fig. 3** of the
5 drawing. The unit is preferable securely mounted to the
6 dashboard of a golf cart and is wired to obtain its power
7 from the cart batteries. Alternatively, the unit may
8 include batteries and be carried by a golfer.
9 Furthermore, in addition to the visual information
10 displays 38-44 the unit 10 may include a speaker and
11 perhaps a microphone (not shown) to permit audible
12 communication as well.

13 The base station 14 is generally located in the
14 clubhouse or pro shop of the golf course and includes a
15 general purpose computer 52 with custom software, a modem
16 54, a GPS receiver 56, a GPS antenna 58, a radio modem 60
17 and a radio antenna 62. The base station computer 52 is
18 used to generate display messages to each of the mobile
19 units, to order additional rounds of play from the system
20 owner, store credits or prepurchased golf rounds,
21 configure the mobile units for the daily pin locations,
22 store the course configuration information, and provide
23 system accounting information. The base station GPS
24 receiver 56 receives satellite data, calculates the
25 differential correction (offset) data, and with the aid of
26 computer 52 sends it to the mobile range finder units via
27 the base station radio 60. Such computation could also be
28 done by the base station computer 52 if the GPS receiver
29 does not have the capability. Data received from the host
30 computer 64 at the remote office 16 via the hookup of
31 modems 68 and 54 is used for accounting information or is
32 sent via the radio modems 60 and 34 to the mobile range
33 finders.

34 The remote office 16 includes a general purpose
35 computer 64 with custom software and a modem 68. The host
36 computer 64 is used by the system executive or owner to
37 allow a base station operator to automatically purchase

1 and download additional usages of the mobile range finder
2 units. It also provides a means for the system owner to
3 communicate with the base station computer and therefore
4 each mobile range finder unit. This communications
5 network can also be used to provide display information to
6 the mobile range finder units as well as giving the system
7 owner the ability to perform remote diagnostics and
8 provide program updates to both the base station, or
9 stations, and the mobile range finder units.

10 In Fig. 3 of the drawing, the simplicity of use of
11 the present invention is suggested by the depiction of a
12 mobile unit 10 of the type that might be mounted on a golf
13 cart. As previously mentioned, upon start of a round the
14 elapsed time clock 44 will commence keeping time. The
15 hole number being played will be selected using buttons 37
16 and 39 and indicated at 38. In case holes are played out
17 of order, one can change the hole number by pressing one
18 of the UP or DOWN buttons 37 or 39. Following
19 commencement of play the initial yardage to the hole or
20 flag will be indicated on indicator 40.

21 If the player wishes to determine the distance to the
22 front edge of a hazard, the pressing of button 41 will
23 cause the yardage indicated in the display 40 to change to
24 indicate such distance. Similarly, if the button 43 is
25 depressed, the distance required to clear the hazard will
26 be indicated. Furthermore, if there is a significant
27 difference between the course altitude and the altitude of
28 the green or hazard, the altitude difference may be
29 displayed in the window 46.

30 If after having hit a particular shot, the golfer
31 pushes his START button 45, and then after having arrived
32 at the position of his ball, pushes the END button 47, the
33 length of his shot will be displayed at 42. Note that the
34 distance of each players' shot can be alternatively
35 indicated by pressing buttons 45/47. Although a
36 particular combination of buttons and displays is
37 illustrated, any similar configuration can be used.

1 During play the subsystem can automatically generate
2 appropriate messages for display on the two lines 46, or
3 alternatively, messages transmitted from the base station
4 or remote office can be displayed. Note also that if the
5 unit includes transmission capability it may also have a
6 microphone and speaker, and perhaps an expanded keyboard
7 to permit data entry.

8 Turning now to **Fig. 4**, the principal functional
9 components of the control circuit 48 of the mobile unit 10
10 are depicted in block diagram form. The circuit is a
11 custom designed assembly including Universal Asynchronous
12 Receivable Transmitters (UART's) 70 and 72, a
13 microprocessor 74, random access memory 76, program
14 storage memory 78, and read only memory or flash
15 programmable memory, display drivers 80 and a power supply
16 82.

17 The microprocessor 74 receives position data via the
18 UART 70 from the mobile unit's GPS receiver 30, receives
19 display information, configuration data, program updates
20 and differential correction data via UART 72 which
21 communicates via modems 34 and 60 (**Fig. 2**) with the base
22 station computer 52. The microprocessor also receives
23 user control inputs via input line 49 from the key pad 50
24 (**Figs. 2 and 3**).

25 Each mobile unit's GPS receiver and the base
26 station's GPS receiver are capable of tracking, receiving
27 data from multiple satellites and normally selects a set
28 of the four satellites with best geometry to utilize in
29 making its calculation. **Fig. 5** is a flow chart providing
30 a basic indication of how a GPS receiver calculates the
31 location of the receiver and **Fig. 6** is a flow chart
32 illustrating how the differential correction data is
33 generated and applied.

34 More specifically, ranging signals are provided by
35 the NAVSTAR satellites and are received by the GPS
36 receivers as indicated in **Fig. 5**. Upon receiving the
37 satellite data, each receiver calculates the distance

1 (pseudorange) from each selected satellite to the
2 receiver. Each distance is given by the formula

3

$$4 \quad PR_i = \Delta T_i \times c$$

5

6 where PR_i is the pseudorange from satellite i , T_i is the
7 time it takes the range signal to travel from satellite i
8 to the GPS receiver, and c is the speed of light.

9 In addition to range signals, the satellites transmit
10 satellite ephemeris data to the receiver, i.e., a list of
11 accurate locations of the satellites as a function of
12 time. This gives the receiver the location of each
13 satellite expressed as X_i , Y_i and Z_i . The variable i is
14 used to designate the satellite. With the data from the
15 four best satellites (b , c , d and e in **Fig. 1**) that are in
16 view of the GPS antenna, the receiver's data processor
17 solves a matrix of four equations for four variables:

18

$$19 \quad (X_1 - UX)^2 + (Y_1 - UY)^2 + (Z_1 - UZ)^2 = (PR_1 - (CB \times c))^2$$

$$20 \quad (X_2 - UX)^2 + (Y_2 - UY)^2 + (Z_2 - UZ)^2 = (PR_2 - (CB \times c))^2$$

$$21 \quad (X_3 - UX)^2 + (Y_3 - UY)^2 + (Z_3 - UZ)^2 = (PR_3 - (CB \times c))^2$$

$$22 \quad (X_4 - UX)^2 + (Y_4 - UY)^2 + (Z_4 - UZ)^2 = (PR_4 - (CB \times c))^2$$

23

24 The variables UX , UY and UZ are respectfully the
25 latitude, longitude and altitude of the receiver, and CB
26 is the receiver clock bias. The receiver clock bias is
27 the difference between the satellite time and the receiver
28 time. This data incorporates errors which include
29 pseudorandom errors injected by the DOD and additional
30 system errors such as satellite clock bias, atmospheric
31 distortion and gravitational effects. These errors limit
32 the accuracy of the basic GPS to approximately 100 meters.

33 **Fig. 6** depicts the calculation and application of the
34 differential correction data which is required to improve
35 the system accuracy to within approximately two yards as
36 required in the sport of golf. The base station GPS
37 receiver is fixed in location and the exact actual
38 location of the receiver given by the coordinates AX , AY

1 and AZ is determined at the time of installation utilizing
 2 GPS survey techniques. The base station GPS receiver is
 3 given this location by the base station computer and uses
 4 such information along with the basic GPS location
 5 calculations of UX, UY and UZ to determine the error
 6 associated with the pseudorange data (PRC_i) from each
 7 satellite that is being tracked by the base station GPS
 8 receiver. This pseudorange correction data is sent from
 9 the base station GPS receiver to the base station computer
 10 which, in turn, sends the data to the mobile units via the
 11 radio modems. The receiver in each mobile unit solves the
 12 basic set of equations as set forth above with the added
 13 pseudorange correction factor PRC_i as follows:

14

$$\begin{aligned} 15 \quad & (X_1 - UX)^2 + (Y_1 - UY)^2 + (Z_1 - UZ)^2 = ((PR_1 + PRC_1) - (CB \times c))^2 \\ 16 \quad & (X_2 - UX)^2 + (Y_2 - UY)^2 + (Z_2 - UZ)^2 = ((PR_2 + PRC_2) - (CB \times c))^2 \\ 17 \quad & (X_3 - UX)^2 + (Y_3 - UY)^2 + (Z_3 - UZ)^2 = ((PR_3 + PRC_3) - (CB \times c))^2 \\ 18 \quad & (X_4 - UX)^2 + (Y_4 - UY)^2 + (Z_4 - UZ)^2 = ((PR_4 + PRC_4) - (CB \times c))^2 \end{aligned}$$

19

20 Generally stated, the method of the present invention
 21 is depicted in **Figs. 7a** and **7b** and includes the following
 22 steps:

23 (a) Using a mobile first GPS receiver to obtain
 24 signals transmitted from at least three (and preferably
 25 four) NAVSTAR satellites and to calculate first
 26 pseudorange data based on the time at which each
 27 transmitted signal is received by the mobile receiver;

28 (b) Using a second GPS receiver disposed at a fixed,
 29 known position to obtain signals transmitted from at least
 30 three (and preferably four) NAVSTAR satellites and to
 31 calculate second pseudorange data based on the time at
 32 which each transmitted signal is received by the second
 33 GPS receiver;

34 (c) Using the calculated second pseudorange data to
 35 determine the measured position of the base station;

36 (d) Using the known position and the measured
 37 position to develop a differential correction offset
 38 signal;

1 (e) Transmitting the differential correction offset
2 signal to the remote mobile receivers;

3 (f) Receiving the transmitted differential
4 correction offset signal at the remote mobile receiver and
5 using it and the first pseudorange data to determine the
6 actual position of the mobile unit; and

7 (g) Using the actual position information to
8 determine and indicate the distance between the mobile
9 unit and a known position on the golf course.

10 The following additional steps can also be
11 implemented:

12 (h) Using the actual position information obtained
13 at one location and the actual position information
14 subsequently obtained at another location to calculate the
15 distance between the two locations;

16 (i) Transmitting the actual position information
17 back to the base station; and

18 (j) Receiving the transmitted actual position
19 information at the base station and using same to monitor
20 the travel of the mobile unit over the golf course.

21 Moreover, if signals from four satellites are
22 processed the indication provided in step (g) can also
23 include the difference in altitude between the mobile unit
24 and the known position of the golf course.

25 As pointed out above, the method can also include
26 transmission of information in both directions between the
27 mobile unit and the base station, transmission of
28 information in both directions between the remote office
29 and the base station, and control of mobile unit and/or
30 base station operation from the remote office, etc.

31 Whereas the best available prior art golf distance
32 measurement systems use only three land based transmitters
33 and do not provide for switching to an optimum set of
34 transmitters to insure best accuracy, in accordance with
35 the present invention, multiple satellite signals can be
36 received and the best combination thereof automatically
37 and dynamically selected to calculate the most accurate

1 position based upon relevant signal strengths and optimum
2 satellite geometries. While only three satellites are
3 required for a two dimensional solution, and only four are
4 required for a three dimensional solution, there are
5 currently twenty-four satellites available in the NAVSTAR
6 system with up to eleven in view at any particular time to
7 provide a system usage/capability significantly more
8 independent of terrain or location than was previously
9 available in the prior art.

10 The present invention provides a triangulation
11 capability in a "vertical" orientation versus the
12 "horizontal" orientation of the prior art, land-based
13 systems. This makes it possible to provide the height
14 difference between the golfer's location and the green, a
15 measurement that was not possible with prior art devices.
16 This vertical orientation allows wide spread use of the
17 technology in the sport of golf, where the prior art was
18 inaccurate, unreliable or even unusable in those golf
19 course locations where terrain or buildings, such as
20 houses or condominiums, masked or blocked the electronic
21 line-of-site between the transmitter and the player or his
22 cart. The satellite signals used in the present invention
23 are available virtually anywhere on earth and do not
24 require that triangulation transmitters be installed on
25 the golf course.

26 Whereas prior art systems utilize ground based
27 triangulation techniques which essentially solve three
28 equations for the variables X location, Y location and
29 time. The present invention incorporates a real time
30 differential correction system to correct for
31 intentionally injected noise, clock timing errors,
32 atmospheric distortion and other variables. The use of
33 differential correction allows for the resolution of an
34 additional variable, system error, which greatly improves
35 system accuracy.

36 Moreover, the present invention enables the
37 development of an extensive data network that allows the

1 system operator and the system owner to send data to, and
2 receive data from, each mobile range finder unit. The
3 utilization of time multiplexing of radio modems allows
4 the system to transmit golf course configuration data,
5 display messages, diagnostic data, computer program
6 updates and real time differential correction data. The
7 use of flash memory for the mobile unit microprocessor
8 program memory, in conjunction with the data network,
9 allows for program updates and modifications that can be
10 generated automatically. The present invention also
11 includes the capability of automatically down loading
12 usage credits for usage, and simultaneously generating
13 invoices and accounting information.

14 Although the present invention has been described
15 above with regard to a particular preferred embodiment of
16 the present invention. It is contemplated that after
17 having read such disclosure certain alterations and
18 modifications thereof will become apparent to those
19 skilled in the art. It is therefore intended that the
20 following claims be interpreted as covering all such
21 alterations and embodiments as fall within the true spirit
22 and scope of the invention.

23 What is claimed is:

CLAIMS

- 1 1. A system for determining a golfer's position and
2 distance between various points on a golf course,
3 comprising:
4 a base station having a known position and including
5 a global positioning system (GPS) receiver for
6 receiving and using signals transmitted by NAVSTAR to
7 determine its apparent position,
8 computing means for determining a differential
9 position offset equal to the difference between said known
10 position and said apparent position, and
11 transmitter means for transmitting information
12 proportional to said differential position offset; and
13 at least one mobile range finder unit including
14 a GPS receiver for receiving and using signals
15 transmitted by said NAVSTAR satellites to develop an
16 apparent mobile unit position signal,
17 radio receiver means for receiving said
18 differential position offset information, and
19 computing means for using said apparent mobile
20 unit position signal and said differential position offset
21 information to determine the actual position of said
22 mobile unit on said golf course and for determining and
23 developing a distance signal proportional to the distance
24 between said actual position and a selected predetermined
25 position on said golf course, and
26 annunciator means responsive to said distance
27 signal and operative to indicate said distance.
- 1 2. A system as recited in claim 1, wherein said
2 transmitter means also has the capability of transmitting
3 communicative information and, wherein, said receiver
4 means receives said communicative information and in
5 response thereto said annunciator means communicates such
6 information to a golfer associated with said mobile unit.

1 3. A system as recited in claim 1 wherein said mobile
2 unit computing means is capable of determining the
3 distance between any two selected positions of said mobile
4 unit, and said annunciator means is operative to indicate
5 such distance to a golfer associated with said mobile
6 unit.

1 4. A system as recited in claim 3 wherein said
2 annunciator means includes a visual display means for
3 indicating distances in yards.

1 5. A system as recited in claim 2 wherein said
2 annunciator means includes a visual display means for
3 displaying said communicative message.

1 6. A system as recited in claim 1, wherein said mobile
2 unit further includes transmitter means for transmitting
3 said actual position information and/or user input
4 information, and wherein said base station further
5 includes radio receiver means for receiving said
6 transmitted actual position information and/or said user
7 input information.

1 7. A method of determining and indicating the distance
2 between two points on a golf course, comprising:
3 (a) using a mobile first GPS receiver to obtain
4 signals transmitted from at least three NAVSTAR satellites
5 and to calculate first pseudorange data based on the time
6 at which each transmitted signal is received by the mobile
7 receiver;
8 (b) using a second GPS receiver disposed at a fixed,
9 known position to obtain signals transmitted from at least
10 three NAVSTAR satellites and to calculate second
11 pseudorange data based on the time at which each
12 transmitted signal is received by the second GPS receiver;
13 (c) using the calculated second pseudorange data to
14 determine the measured position of the base station;

15 (d) using the known position and the measured
16 position to develop a differential correction offset
17 signal;

18 (e) transmitting the differential correction offset
19 signal to the remote mobile receivers;

20 (f) receiving the transmitted differential
21 correction offset signal at the remote mobile receiver and
22 using it and the first pseudorange data to determine the
23 actual position of the mobile unit; and

24 (g) using the actual position information to
25 determine and indicate the distance between the mobile
26 unit and a known position on the golf course.

1 8. A method as recited in claim 7 and further
2 comprising:

3 (h) Using the actual position information obtained
4 at one location and the actual position information
5 subsequently obtained at another location to calculate the
6 distance between the two locations.

1 9. A method as recited in claim 8 and further
2 comprising:

3 (i) Transmitting the actual position information
4 back to the base station; and

5 (j) Receiving the transmitted actual position
6 information at the base station and using same to monitor
7 the travel of the mobile unit over the golf course.

1 10. A method as recited in claim 7 and further
2 comprising:

3 (k) Using the actual position information obtained
4 at the location of the mobile unit and actual position
5 information regarding another location to calculate the
6 difference in altitude between the two locations.

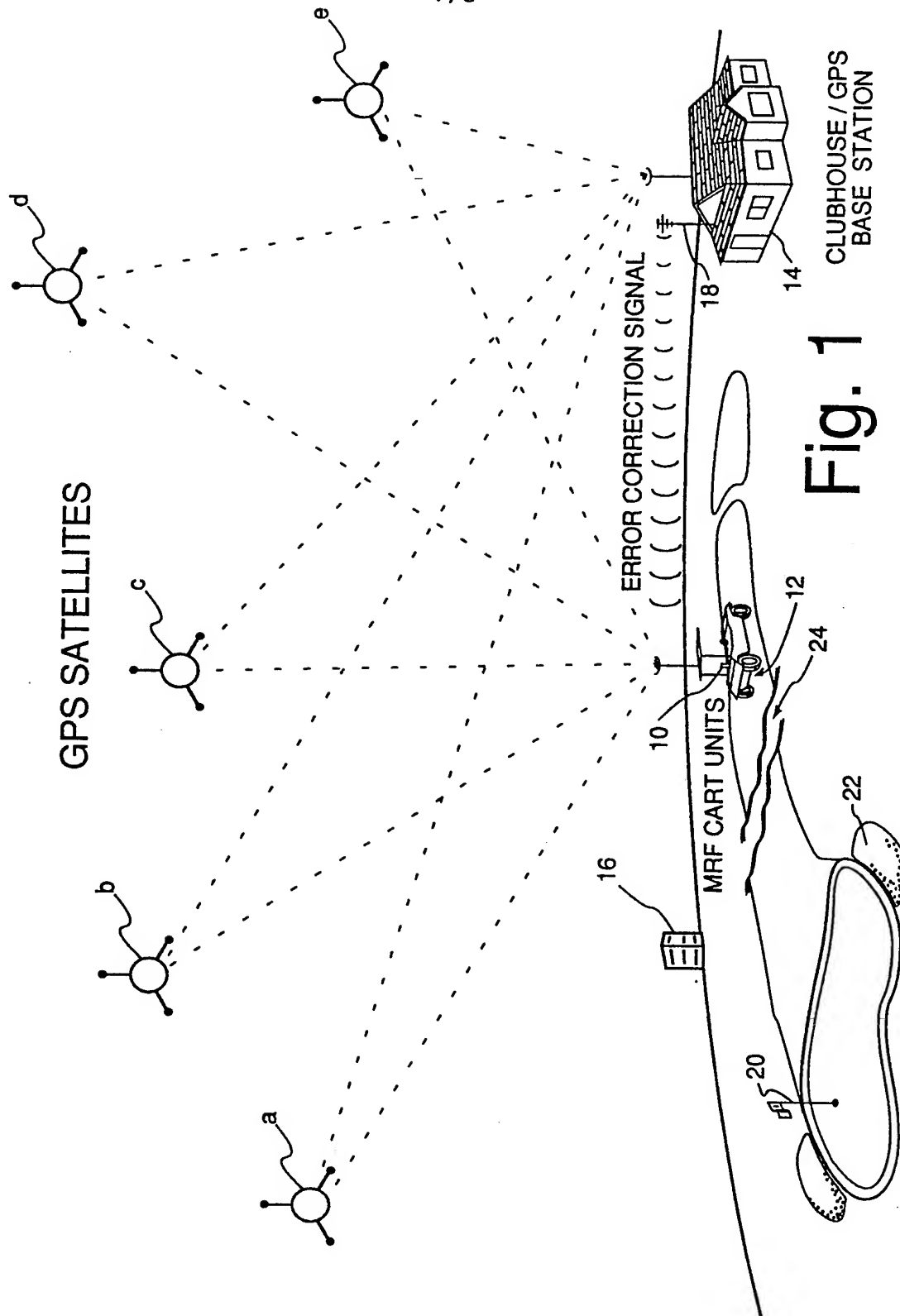


Fig. 1

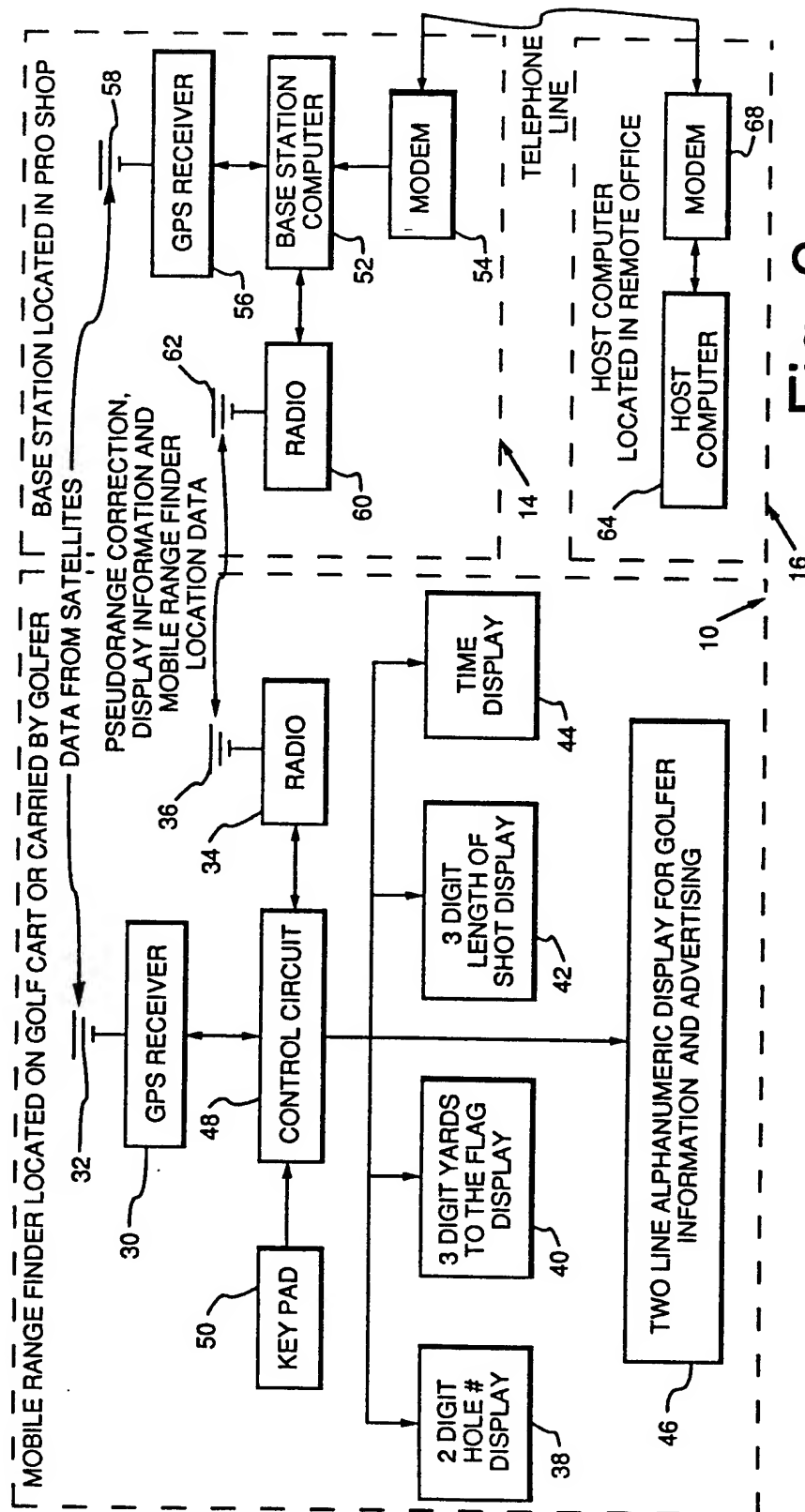


Fig. 2

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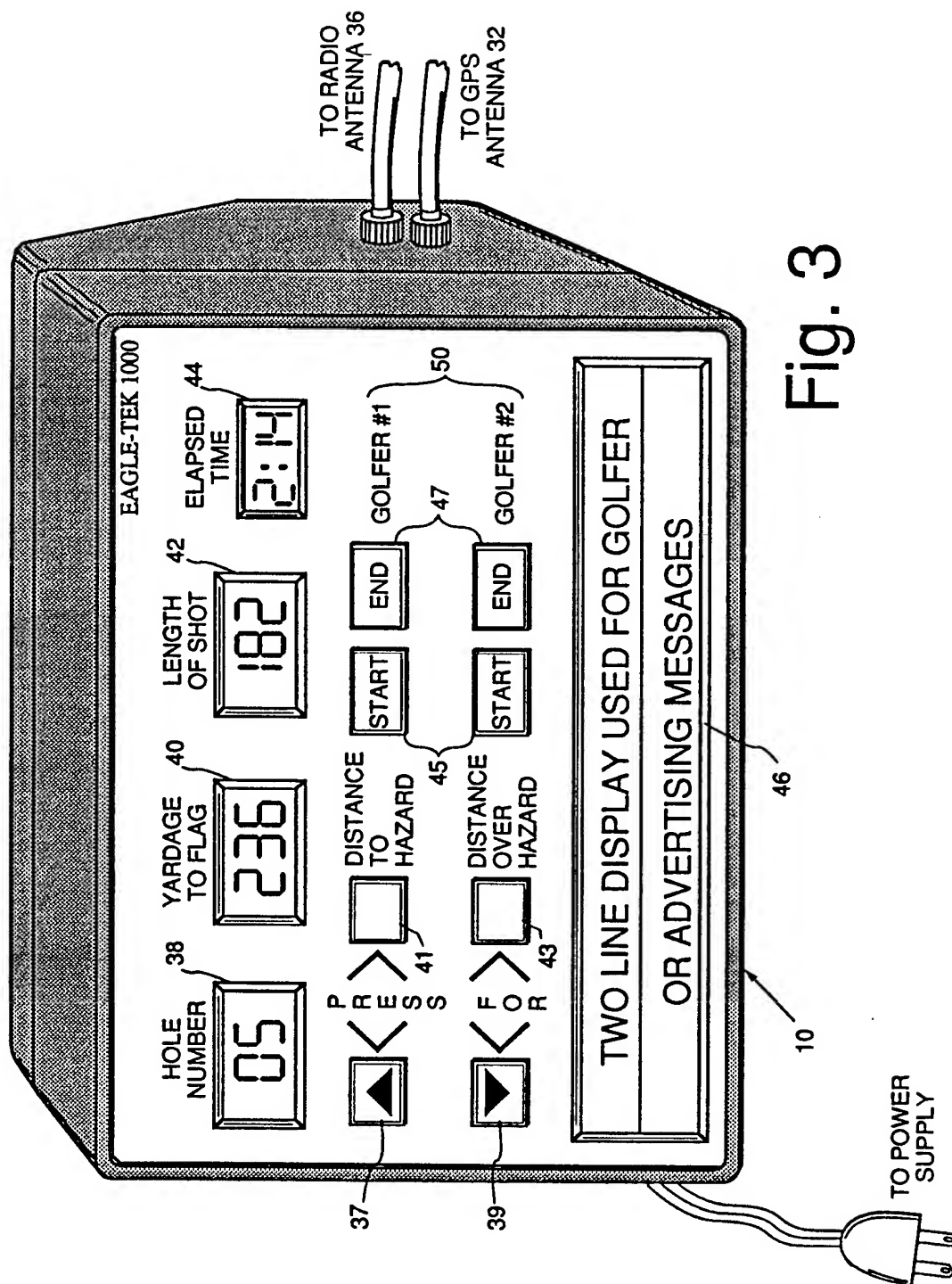


Fig. 3

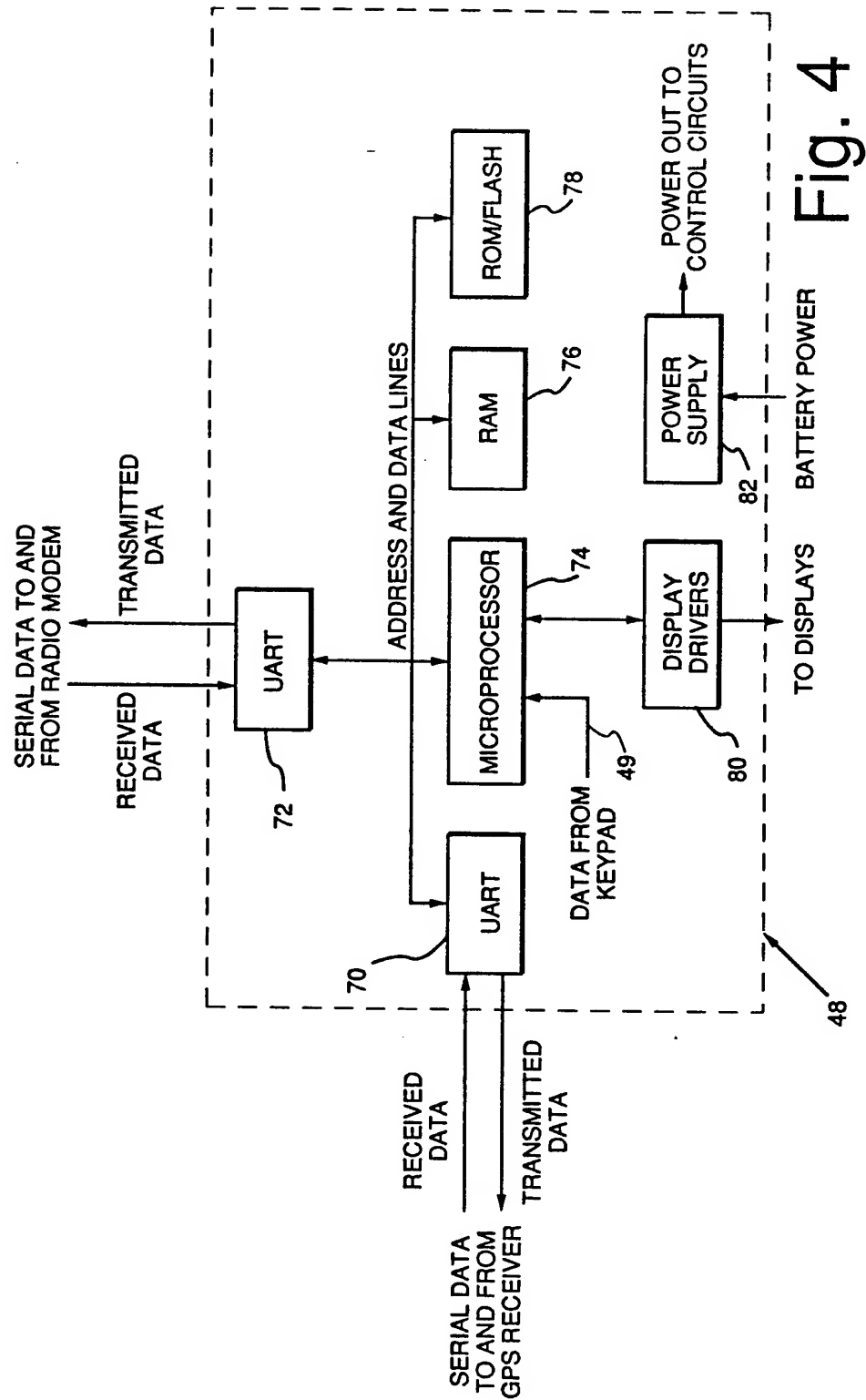


Fig. 4

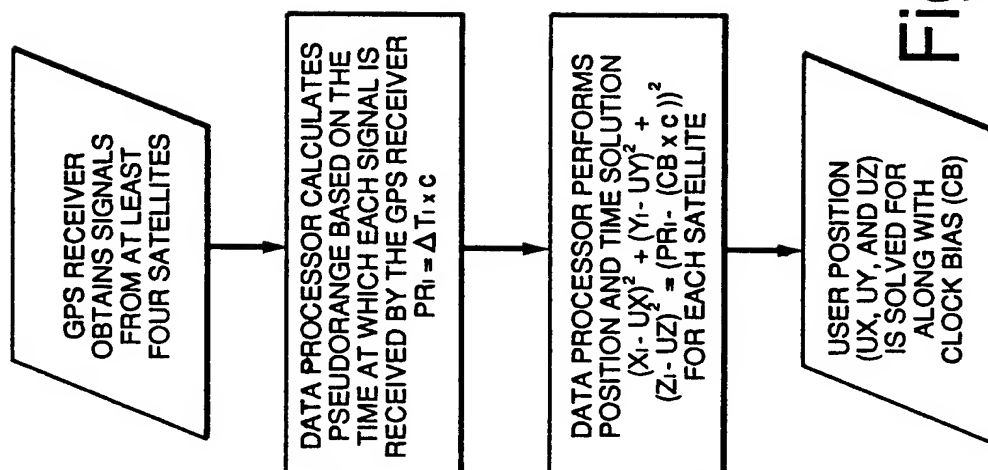


Fig. 5

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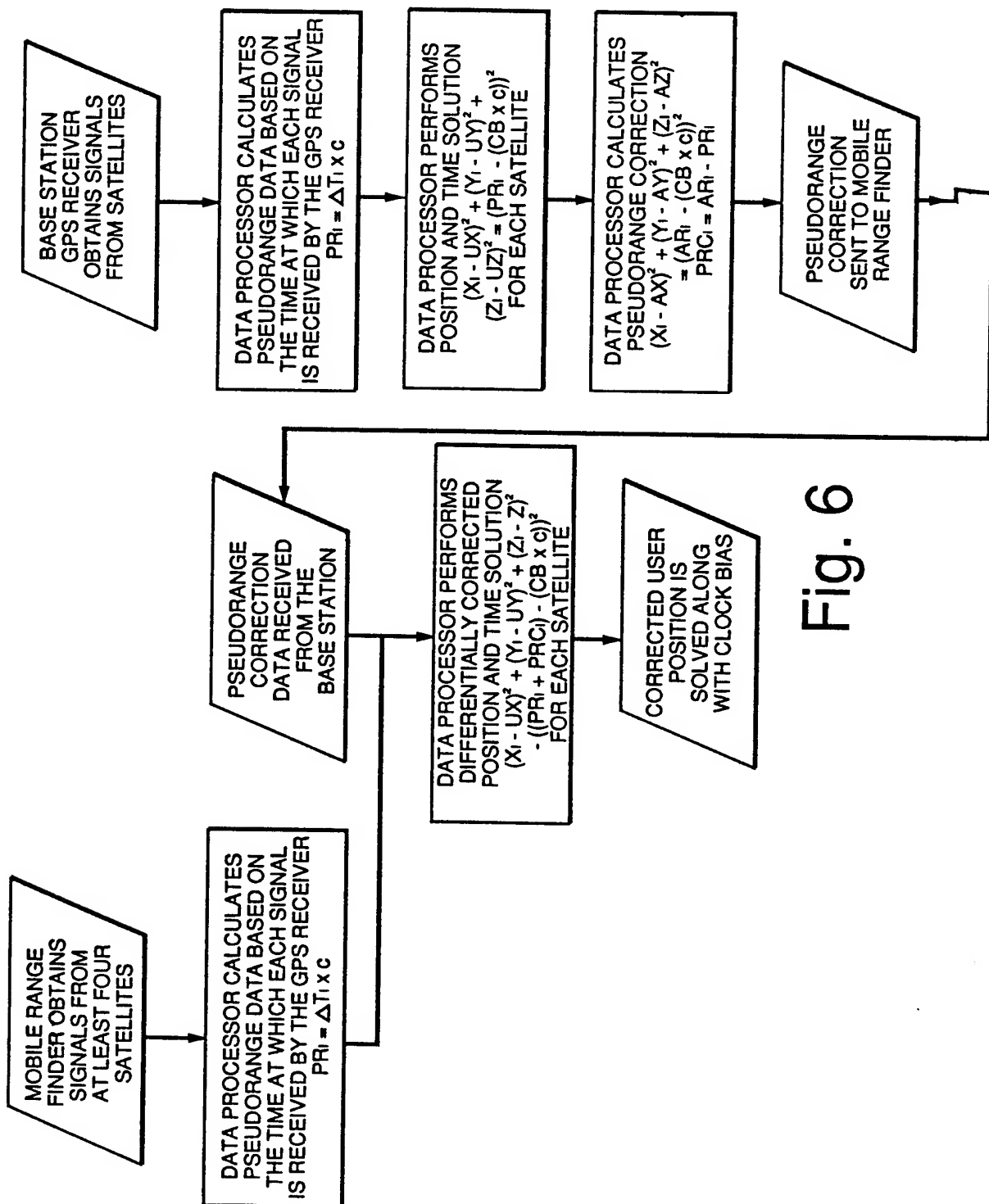


Fig. 6

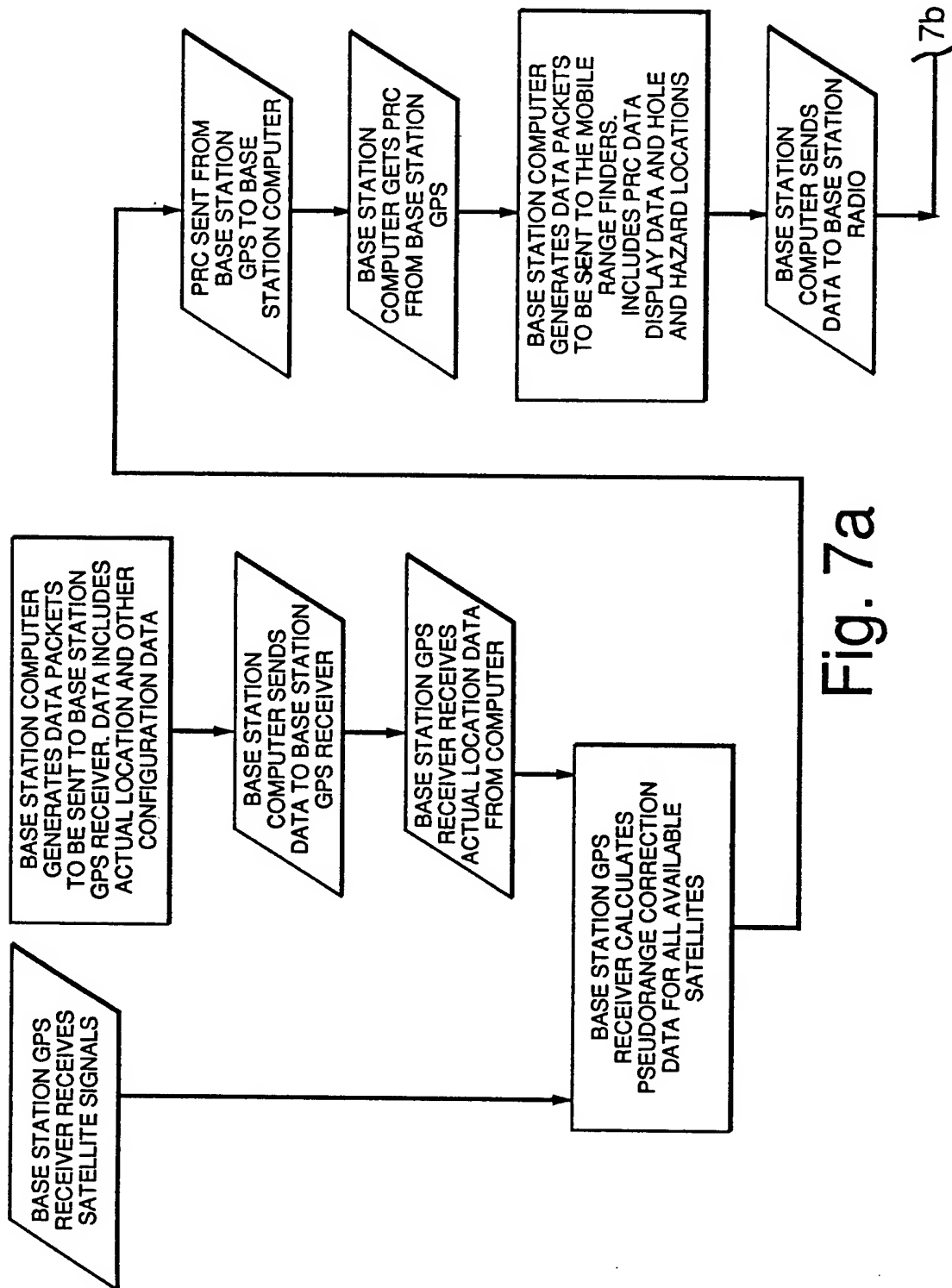
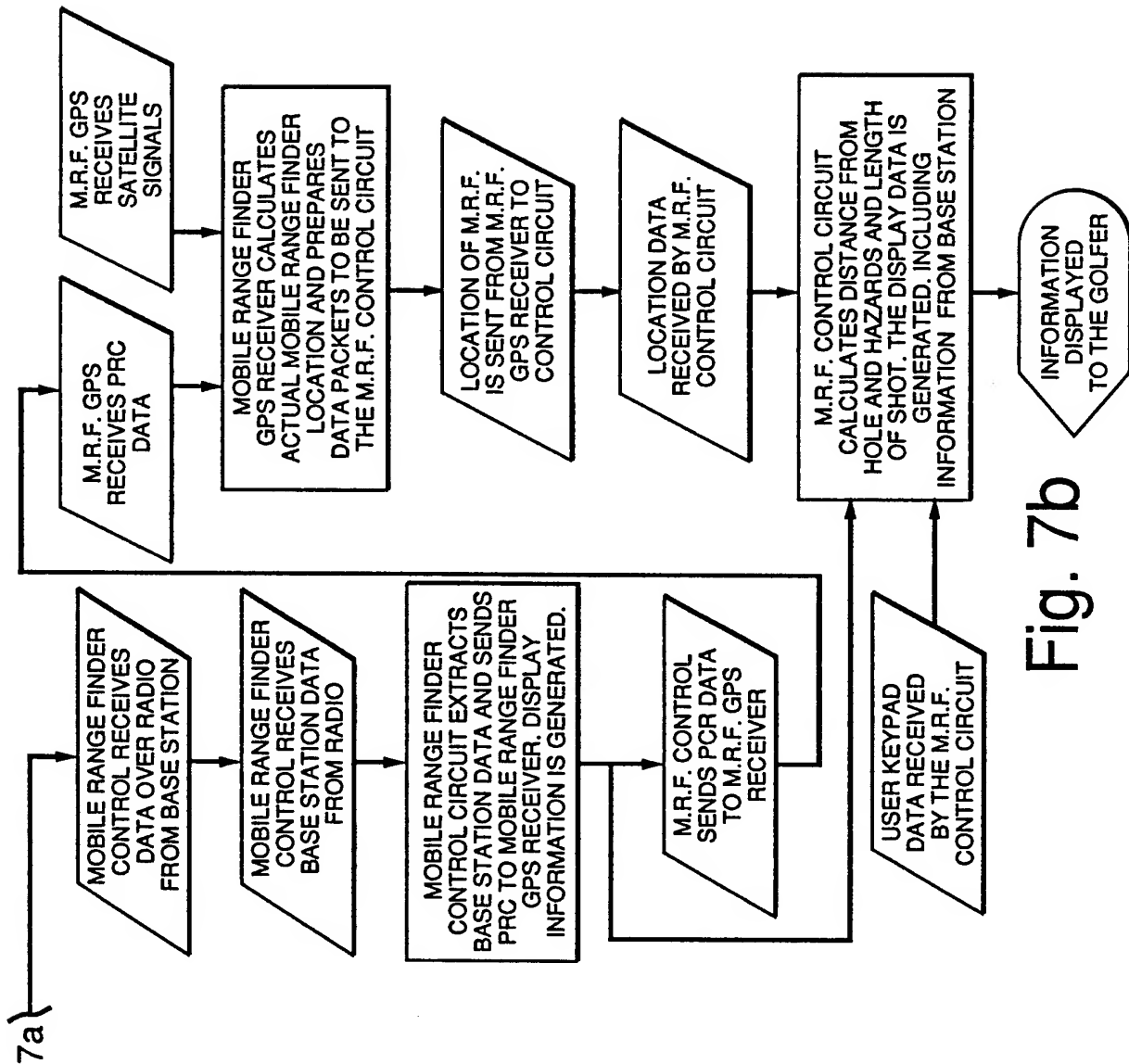


Fig. 7a



INTERNATIONAL SEARCH REPORT

International application No.
PCT/US95/00848

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) : G01S 5/14, 5/02; A63B 71/06, 57/00

US CL : 364/561, 444, 449; 273/32R, 32H; 340/323R

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 364/561, 444, 449, 562, 410; 273/32R, 32H, 34R, 439; 340/323R, 988, 991, 992, 993; 342/357, 457, 118, 123, 126, 352, 450

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

APS search terms: GPS, golf, differential corrections, pseudorange

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X,P	US, A, 5,364,093 (HUSTON ET AL) 15 November 1994, col. 2, lines 5-65; col. 3, lines 35-68; col. 5, lines 1-27; col. 5, line 59 - col. 6, lines 32; col. 4, lines 1-68; col. 6, lines 39-53; col. 6, line 25 - col. 7, line 17.	1-10
Y,P	US, A, 5,359,521 (KYRTSOS ET AL) 25 October 1994, col. 3, line 50 - col. 4, line 68; col. 5, line 39 - col. 13, line 66	1-10
A	US, A, 5,044,634 (DUDLEY) 03 September 1991, col. 1, line 10 - col. 3, line 8	1-10
Y	US, A, 5,225,842 (BROWN ET AL) 06 July 1993, col. 4, line 49 - col. 7, line 68	1-10

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:	*T	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention	
*A	document defining the general state of the art which is not considered to be part of particular relevance		
*E	earlier document published on or after the international filing date	*X	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
*L	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	*Y	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
*O	document referring to an oral disclosure, use, exhibition or other means		
*P	document published prior to the international filing date but later than the priority date claimed	*&	document member of the same patent family

Date of the actual completion of the international search

07 MARCH 1995

Date of mailing of the international search report

04 MAY 1995

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US95/00848

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US, A, 5,119,102 (BARNARD) 02 June 1992, col. 4, line 30 - col. 7, line 15	1-10
A	US, A, 4,703,444 (STORMS, JR ET AL) 27 October 1987, col. 2, line 50 - col. 6, line 44	1-10